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APPLICATION FOR UNITED STATES PATENT

**FLUORESCENT LAMP HAVING REDUCED  
MERCURY CONSUMPTION**

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# FLUORESCENT LAMP HAVING REDUCED MERCURY CONSUMPTION

## BACKGROUND OF THE INVENTION

### Field of the Invention

5       The present invention relates generally to a fluorescent lamp, and more particularly to a fluorescent lamp having reduced mercury consumption.

### Description of Related Art

10       Mercury vapor discharge fluorescent lamps are well known in the marketplace. Their operation depends upon the excitation of mercury vapor atoms via an electric discharge, and the resonance energy given off when the excited atoms return to their ground state. Each lamp therefore contains a quantity of mercury sufficient to  
15       maintain the desired mercury vapor pressure within the sealed lamp (typically 4-6  $\mu\text{m Hg}$ ). So long as the mercury vapor within the lamp remains at the desired pressure, the lamp will continue to operate normally, producing maximum lumens.

20       Unfortunately, mercury vapor is depleted over the lamp's life via a number of known mechanisms. These mechanisms include reaction with phosphor particles or phosphor additives in the phosphor coating, and reaction with the glass envelope itself. Reaction with the glass  
25       envelope is the most significant source of mercury vapor depletion, however both reactions deplete mercury vapor by consuming atomic mercury in a chemical reaction.

30       One solution to this problem has been to provide an alumina or silica barrier layer on the inner surface of the glass envelope to prevent mercury attack. Alumina and silica have been somewhat successful at abating

mercury-glass reactions, however it is known that yttria is more effective than either alumina or silica for this purpose. Yttria barrier layers are not used because the greater cost of yttrium makes yttria barrier layers  
5 economically unfeasible.

A second solution (often implemented in addition to an alumina or silica barrier layer) has been to dose fluorescent lamps with excess liquid mercury. The result is that as mercury vapor is consumed, more liquid mercury  
10 vaporizes to sustain a dynamic equilibrium at mercury's vapor pressure. However, increasing environmental concerns, as well as state and federal regulation of mercury, are requiring lamp manufacturers to dose fluorescent lamps with less mercury, not more, and excess  
15 liquid mercury is fast becoming a non-option.

There is a need in the art for a means of preventing, or substantially reducing, mercury consumption in fluorescent lamps. Such means preferably would eliminate the need for dosing a fluorescent lamp  
20 with substantial excess liquid mercury. Further, such means preferably would provide the benefits of yttria without necessitating a yttria barrier layer.

#### SUMMARY OF THE INVENTION

25 A mercury vapor discharge lamp is provided which has a light-transmissive glass envelope with an inner surface, means for providing a discharge, a barrier layer coated adjacent the inner surface of the glass envelope, a phosphor layer coated adjacent the inner surface of the  
30 barrier layer, and a fill gas of mercury and an inert gas sealed inside the envelope. The barrier comprises

barrier layer substrate particles and 0.1-10 wt.% yttria. The barrier layer also has crystalline yttria particles uniformly dispersed throughout.

A mercury vapor discharge lamp is also provided which has a light-transmissive glass envelope with an inner surface, means for providing a discharge, a phosphor layer coated adjacent the inner surface of the glass envelope, and a fill gas of mercury and an inert gas sealed inside the envelope. The phosphor layer comprises phosphor particles and 0.001-10 wt.% yttria. The phosphor layer also has crystalline yttria particles uniformly dispersed throughout.

A method of providing a coating layer in a fluorescent lamp is also provided. The method comprises the steps of **a)** providing a suspension of 1-10 wt.% coating layer substrate particles in a suspension medium of deionized water; **b)** dissolving a yttrium salt in the suspension; **c)** adding hydrochloric acid to the suspension to bring the suspension to a pH of 3-6; **d)** applying the suspension to the inner surface of a glass envelope of a fluorescent lamp; **e)** drying the suspension coated on the inner surface of the glass envelope to provide a partially dried coating layer wherein the dissolved yttrium salt is at least partially recrystallized thereby; and **f)** baking the coating layer to dry the coating layer and to oxidize the recrystallized yttrium salt to yttria. The yttria is dispersed throughout the coating layer.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a first preferred embodiment of a

mercury vapor discharge fluorescent lamp according to the present invention.

FIG. 2 shows a second preferred embodiment of a mercury vapor discharge fluorescent lamp according to the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

In the description that follows, when a preferred range, such as 5 to 25 (or 5-25), is given, this means preferably at least 5, and separately and independently, preferably not more than 25.

As used herein, a "fluorescent lamp" is any mercury vapor discharge fluorescent lamp as known in the art, including fluorescent lamps having electrodes, and electrodeless fluorescent lamps where the means for providing a discharge include a radio transmitter adapted to excite mercury vapor atoms via transmission of an electromagnetic signal.

Also as used herein, a "T8 lamp" is a fluorescent lamp as known in the art, preferably linear, preferably nominally 48 inches in length, and having a nominal outer diameter of 1 inch (eight times 1/8 inch, which is where the "8" in "T8" comes from). Less preferably, the T8 fluorescent lamp can be nominally 2, 3, 6 or 8 feet long, less preferably some other length.

Fig. 1 shows a mercury vapor discharge fluorescent lamp 10 according to a first preferred embodiment of the present invention. Though the lamp in Fig. 1 is linear, the invention is not limited to linear lamps and may be

applied to fluorescent lamps of any shape. The fluorescent lamp 10 has a light-transmissive glass tube or envelope 12 which has a circular cross-section.

The lamp is hermetically sealed by bases 20 attached  
5 at both ends and, in lamps having electrodes (such as that in Fig. 1), a pair of spaced electrode structures 18 are respectively mounted on the bases 20. A discharge-sustaining fill gas 22 of mercury and an inert gas is sealed inside the glass tube. The inert gas is  
10 preferably argon or a mixture of argon and krypton, less preferably some other inert gas or gas mixture. The inert gas and a small quantity of mercury vapor provide the low vapor pressure manner of operation. Preferably, the mercury vapor has a pressure of 4-6  $\mu\text{m Hg}$ ,  
15 approximately mercury's vapor pressure at 25°C.

In the first preferred embodiment, the fluorescent lamp 10 has a barrier layer 14, and a phosphor layer 16. Barrier layer 14 comprises substrate particles that make up the principal component of the barrier layer. In this  
20 embodiment, the barrier layer 14 is coated adjacent, preferably directly on, the inner surface of the glass envelope 12, and the phosphor layer 16 is coated adjacent, preferably directly on, the inner surface of the barrier layer 14. The barrier layer 14 is preferably  
25 an alumina barrier, wherein the barrier layer substrate particles are alumina particles. Preferably, barrier layer 14 comprises a mixture of substantially equal proportions of alpha- and gamma-alumina particles as the substrate particles. Less preferably or alternatively,  
30 the barrier layer can be a silica, hafnia, zirconia, vanadia, or niobia barrier layer, less preferably some

combination or mixture thereof.

A preferred alumina barrier layer has a coating weight of 0.05-3, preferably about 0.12-0.15, mg/cm<sup>2</sup>. The alumina particles preferably have a mean particle size of 5 15-800, preferably 20-600, preferably 20-400, preferably 22-300, preferably 25-200, preferably 30-100, nm.

Barrier layer 14 also comprises a quantity of crystalline yttria uniformly dispersed among the alumina particles.

Most preferably, the alumina particles in barrier layer 10 14 and the inner surface of glass envelope 12 also have a film of crystalline yttria substantially uniformly disposed or coated over their respective surfaces.

Preferably, barrier layer 14 comprises 0.1-10, preferably 0.4-8, preferably 0.6-6, preferably 1-4, preferably 1.5- 15 3, preferably about 2, wt.% yttria, balance alumina.

Phosphor layer 16 preferably is a rare earth phosphor layer, such as a rare earth triphosphor layer known in the art. Less preferably, phosphor layer 16 can be a halophosphate phosphor layer as known in the art.

20 Phosphor layer 16 preferably has a coating weight of 1-5 mg/cm<sup>2</sup>.

A lamp according to the first preferred embodiment exhibits substantially reduced mercury consumption via reaction with glass envelope 12 due to the presence of 25 yttria in the barrier layer 14. The uniformly deposited yttria film has been shown to be very effective at abating mercury consumption by the glass envelope without the need of a fully yttria-constituted barrier layer. Further, the presence of yttrium ions in the alumina 30 coating suspension promotes resistance to wash-off during subsequent phosphor coating steps.

Fig. 2 shows a lamp according to a second preferred embodiment of the invention, where the fluorescent lamp 10 has a phosphor layer 16, but no barrier layer 14. In this embodiment, the phosphor layer 16 is coated adjacent, preferably directly on, the inner surface of the glass envelope 12. Phosphor layer 16 is preferably a rare earth phosphor layer, such as a rare earth triphosphor layer known in the art. Less preferably, phosphor layer 16 can be a halophosphate phosphor layer as known in the art. Phosphor layer 16 preferably has a coating weight of 1-5 mg/cm<sup>2</sup>.

The phosphor layer 16 also comprises a quantity of crystalline yttria uniformly dispersed among the phosphor particles. Most preferably, the phosphor particles in phosphor layer 16 and the inner surface of glass envelope 12 have a film of crystalline yttria substantially uniformly disposed or coated over their respective surfaces. Preferably, phosphor layer 16 has 0.001-10, preferably 0.01-5, wt.% yttria. The balance of the phosphor layer comprises halophosphors, or rare earth phosphors, where individual phosphors (e.g., red-, blue-, and green-emitting rare earth phosphors) are combined as known in the art in the proper proportions to achieve a fluorescent lamp having desired color temperature and CRI characteristics. The proportions of individual phosphors necessary to provide a desired lamp are essentially unaffected by the presence of yttria particles. Furthermore, a phosphor layer according to the present embodiment, that is prepared according to the method described below, results in a yttria film over the surface of individual phosphor particles that is



sufficiently thin to avoid, or to substantially avoid, adverse optical effects.

A lamp according to this embodiment exhibits substantially reduced mercury consumption via reaction with glass envelope 12 due to the presence of yttrium in the phosphor layer 16. In addition, mercury consumption by reaction with phosphor particles or phosphor additives is also substantially reduced. A phosphor layer comprising 0.001-10 wt.% yttria and constituted as here described results in no, or negligible, reduction in lumen output. Thus, the invented phosphor layer effectively prevents or substantially reduces mercury depletion in the fluorescent lamp, thus providing the benefits of yttria without the high cost or lumen loss associated with a principally constituted yttria layer.

Optionally, phosphor layer 16 contains 0.5-4, preferably 0.6-3, preferably 0.7-2, preferably 0.8-1.5, preferably about 1, wt.% colloidal alumina particles to promote cohesion of the phosphor layer and adhesion to the glass envelope. A phosphor layer according to this embodiment is very effective at abating mercury consumption (via reaction with the glass envelope or phosphor particles) without a separate barrier layer. Thus the additional materials, time and cost associated with a barrier layer coating step are eliminated.

A lamp according to either the first or second preferred embodiment above need be dosed with significantly less liquid mercury to maintain the desired 4-6  $\mu\text{m}$  Hg vapor pressure during the lamp's life. For a typical existing T8 lamp, mercury dosing can range from 7 mg all the way to 40 mg initial mercury content.

Currently, the lowest mercury-dose T8 lamps have from 7 to 9 mg of mercury. A comparable invented lamp having similar performance and longevity is dosed with less than 5 mg, preferably less than 4.5, 4, or 3.5, mg, preferably between 3-3.5 mg, of mercury. That represents about a 50% decrease in mercury without sacrificing lumens or longevity.

A preferred method for providing an alumina barrier coating layer according to the first preferred embodiment will now be described. Differences in the method for preparing a phosphor coating layer according to the second preferred embodiment will be indicated parenthetically.

The barrier layer is initially prepared as an aqueous suspension or slurry, and the slurry is then coated on the inside surface of the glass envelope 12 by known coating means. The suspension is prepared as follows. Deionized water is provided as the suspension medium. The alumina (or phosphor) particles are added to the suspension medium to make up about 1-10, preferably 1-5, wt.% of the total suspension. Next, the remaining non-dissolving components are added in conventional amounts to the suspension medium and stirred or homogenized to form a stable aqueous suspension. The non-dissolving components include thickeners, dispersants and other additives to regulate the suspension's physical properties. Preferred thickeners are nonionic, water soluble polymeric thickeners such as POLYOX (polyethylene oxide). Suitable dispersants are nonionic and include Pluronic F108 and Igepal CO-530. Pluronic F108 is a block copolymer surfactant mixture of

polyoxyethylene and polyoxypropylene available from BASF. Igepal CO-530 is nonylphenol ethoxylate and is available from Rhodia.

Next, a yttrium salt is added to the suspension such  
5 that the proportion of yttrium salt to the alumina (or  
phosphor) particles is equal to that stated above for the  
barrier (or phosphor) layer. Other suspension  
components, such as water and dispersants, are not  
factored into the yttrium salt weight percent  
10 calculation. Preferred yttrium salts are yttrium  
chloride and yttrium nitrate, though any water soluble  
organic or inorganic yttrium salt can be used; (e.g.  
suitable organic yttrium salts include yttrium acetate  
and yttrium carbonate). Once the yttrium salt has been  
15 dissolved in the aqueous suspension and stirred to  
uniform composition, aqueous hydrochloric acid is added  
to bring the suspension to a pH of 3-6 to avoid the  
formation of insoluble yttrium hydroxide. Preferably,  
the HCl solution is about 3.5 wt.% HCl or about 1.2M  
20 HCl<sub>(aq)</sub>.

The suspension is then applied to the inner surface  
of glass envelope 12 by known coating means. Once  
applied, the coating is partially dried via forced air  
convection, and then baked at an elevated temperature,  
25 e.g. at least 400°C, 500°C or 600°C for about 0.5-10  
minutes. As the water is vaporized from the suspension,  
the concentration of the dissolved yttrium salt  
approaches saturation. Yttrium salts are highly soluble  
in water. Hence, the yttrium salt concentration rises  
30 uniformly throughout the coating layer as the water  
evaporates such that once saturation is achieved and the

5 salt begins to crystallize, a highly uniform dispersion  
of yttrium salt crystals is formed, as well as a thin  
yttrium salt film over all of the available surfaces.  
The film forms over the surfaces of the glass envelope 12  
and of the individual alumina (or phosphor) particles.  
Under baking conditions, the yttrium salt is oxidized to  
yttrium oxide (or yttria), thus providing the yttria  
dispersion and yttria film of the present invention. It  
should be noted that yttrium salt crystallization, and  
10 oxidation to yttria, may (and very likely do) occur  
simultaneously, or at least overlap. It is not intended  
that crystallization and oxidation must occur in two  
discrete steps.

It is important that the yttria purity is  
15 sufficiently high, preferably at least 95, preferably 96,  
preferably 97, preferably 98, preferably 99, wt.%, to  
minimize light absorption or formation of light absorbing  
color centers. Unfortunately, most commercially  
available yttrium salts are not very pure. A preferred  
20 method for obtaining a high purity yttrium salt is to  
dissolve commercially available high purity yttrium oxide  
(yttria) in  $\text{HCl}_{(\text{aq})}$  or  $\text{HNO}_3_{(\text{aq})}$  followed by neutralization  
to pH 7.0.  $\text{HCl}$  will yield soluble yttrium chloride and  
 $\text{HNO}_3$ , yttrium nitrate. This neutral yttrium salt solution  
25 is then added to the suspension to achieve the  
appropriate yttria weight percent as explained above.

The invention will be further understood in  
conjunction with the following example.

#### EXAMPLE 1

30 Three fluorescent lamps were constructed. The first

lamp (Lamp 1) had an alumina barrier layer coated on the interior surface of the glass envelope, and a rare earth triphosphor layer coated on the interior surface of the barrier layer. Neither layer contained yttria. The

5 second lamp (Lamp 2) had only a rare earth triphosphor layer coated on the interior surface of the glass envelope; i.e. no barrier layer. The triphosphor layer contained no yttria. The third lamp (Lamp 3) also had only a rare earth triphosphor layer, but with 1 wt.%  
10 yttria added to the triphosphor layer. All three lamps were started and allowed to burn for 100 hours. Mercury consumption was measured in all three lamps with the following results:

Lamp 1: 3% loss by weight of mercury after 100 hrs.

15 Lamp 2: 18% loss by weight of mercury after 100 hrs.

Lamp 3: 5% loss by weight of mercury after 100 hrs.

As can be seen, Lamp 3 containing the yttria dispersed phosphor layer, and no barrier layer, prevented mercury consumption nearly as well as Lamp 1 which  
20 included a barrier layer. It will be understood that by eliminating the need for a barrier layer to abate mercury consumption, a coating step is eliminated from the lamp making process.

While the invention has been described with  
25 reference to a preferred embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be  
30 made to adapt a particular situation or material to the teachings of the invention without departing from the

essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all  
5 embodiments falling within the scope of the appended claims.